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THOUGHTS SUGGESTED BY PROFESSOR DEWAR'S DISCOVERIES.

BY R. OGDEN DOREMUS, M. D., LL. D., PROF. OF CHEMISTRY AND PHYSICS, COLLEGE OF THE CITY OF NEW YORK, AND PROF. OF CHEMISTRY, TOXICOLOGY, AND MEDICAL JURISPRUDENCE, BELLEVUE HOSPITAL MEDICAL COLLEGE.

IN 1654 the reigning Emperor of Germany, Ferdinand III., with his court, honored the inventor of the air pump, Otto von Guericke, by witnessing his experiments. Among other tests von Guericke applied the carefully ground edges of metallic hemispheres, two feet in diameter, to each other. After exhausting them of air, he attached fifteen horses to each hemisphere. In vain did they attempt to separate them, because of the enormous pressure of the atmosphere. Torricelli, of Italy, and Pascal, of France, had already devised mercurial, water, and wine barometers, for measuring the same with accuracy, in 1643, but these important discoveries did not attract wide-spread public attention.

Napoleon I., in the beginning of this century, invited Volta from Pisa to Paris to exhibit the marvels of his electric battery to the *savants* of the French capital, and was present at each *séance*. The deepest interest was excited over the civilized world in the newly-revealed modification of electricity.

The Prince of Wales, towards the close of this century, presides at a lecture by Prof. James Dewar, at the Royal Institution,* on "Liquid Air." The ear of the public is now awakened to the liquefaction and solidification of gases.

Aristotle taught the ancient doctrine of the four elements, "earth, air, fire and water," and suggested a fifth, filling space, which he called "ether." Van Helmont, in the sixteenth century, applied the term "gas" to aeriform substances. He said:

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* Founded in 1799 by an American gentleman, Mr. Benjamin Thompson, born near Rumford, Mass.; afterwards known as Count Rumford.

"*Gas est spiritus non-coagulabilis.*" It was a favorite belief in ancient times that gases, ghosts or hobgoblins were invisible existences inhabiting the bowels of the earth. They were protectors of its treasures, antagonistic to humanity, throttling or destroying with violent explosion intruders in mines.

Chemists are now firm believers in spirits. They can make them appear at their bidding, and of every color in the rainbow, varying also in weight, flavor, and chemical potency, good angels and bad ones. They can stimulate them to war with each other, so that the malign influences of one class are destroyed in the conflict. Chemists can materialize the spirits and force them to assume liquid or solid forms.

In former times, by their efficient aid, the chemist could produce the most intense heat. Hence he was called the "Philosopher by Fire." He can now by changing their visible to an invisible condition obtain severest cold. He may therefore add to his title that of the "Philosopher by Frost."

Modern chemistry is built on a spiritual basis. One of these gases (oxygen) exceeds in weight all the other elements on this globe. United mostly with metals, it forms its solid crust and its continents; with another spirit (hydrogen) it forms the waters of its oceans, seas, lakes and rivers. In a gaseous form it is mingled, democratically, with numerous others to form the air. Our atmosphere is the grand reservoir of hosts of spirits. It is the blue ethereal envelope of mother earth: the cerulean mantle worthy of God, the Spirit! It is the aerial laboratory in which the great problems of existence are solved—"the cradle of vegetable and coffin of animal life." *

How closely we are related to the world of spirits we rarely reflect. We are embodied in them and they are embedded in our bodies. They haunt us when awake, during our daily avocations. They are necessary adjuvants to the arm of labor and the brain of thought. Without their aid we can do nothing. These guardian spirits watch over us while we sleep, and like Vestal virgins, they keep alive the vital flame when our wearied muscles and tired senses repose from their activity, By telescopic aid we behold gaseous investitures enwrapping our associate planets. We know the direction of the winds in some of these remote orbs, by the drifting of their clouds. The spectroscope demonstrates to us that the vastly more distant nebulæ are embryonic gaseous universes, similar in condition to that in which our own system existed, according to the theory of Herschel and Laplace.

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* **Prof. John W. Draper**, *Chemistry of Plants*.

How successfully spirits have eluded human investigators is shown by the years, yea centuries, of observation and research involved in their discovery. Paracelsus in 1500 A. D. noticed the evolution of *air* when sulphuric acid was poured on iron. Seventy-two years passed before its inflammability was discovered by Turquet de Mayerne and also by Boyle. In 1700 Lemery detected its detonating properties when mingled with the atmosphere. In 1766 Macquer and De la Metherie observed that moisture was produced when the gas was burnt. Cavendish in the same year first accurately reported the characteristics of "inflammable air," as he called the gas which was entitled *hydrogen* by Lavoisier in 1774. Over two and a half centuries were required for the discovery of this lightest of all spirits, *hydrogen.*

For the isolation of the gas most essential for the evolution of heat, light, electricity and for the sustenance of animal and human life, namely, *oxygen,* more than two thousand years of patient research were necessary ! In the middle of the sixth century B. C., Heraclitus said: "Air contains a subtile element which sustains fire and respiration." In 480 B. C., Anaximenes of Miletus wrote : "Air is the origin of all things ; and all things return to it after certain evolutions." Eck, of Sulzbach, in the fifteenth century, first demonstrated experimentally that the weight of metals is increased when calcined. In 1630 Brun repeated this discovery after prolonged heating of lead and of tin. In the act of calcination, or, as we now term it, oxidation, they became heavier. Mayow, of England, in 1669, and Priestley, in 1774, released this "vital air," as it was called, by heating red precipitate, oxide of mercury, with the sun's rays through the aid of a lens.

By exposing a growing plant, inclosed in a glass vessel in which a mouse had died for want of pure air, to the same solar rays, Priestley demonstrated the power of the tissue of the green leaf, under this stimulus, to decompose the expired carbonic acid gas from the lungs of the little creature and evolve "vital air." As Dr. Franklin quaintly expressed it, "the plant mended the air." Lavoisier, of France, and Scheele, of Sweden, also discovered this element of elements. To the French philosopher we are indebted for its present name, the acid maker, *oxygen.*

Scheele discovered the following gases—chlorine, hydrocyanic acid, hydrofluoric acid, arseniuretted hydrogen and tetrafluoride of silicon. Nitrogen gas, which forms four-fifths of our atmosphere, was discovered by Rutherford in 1772. "Fixed air," or carbonic acid, was released from carbonates, as now designated by Black in 1755.

In 1823 Prof. Michael Faraday commenced his experiments on the liquefaction of gases, by pressure *alone*, unaided by great cold. He converted the following gases into the liquid state :

	Pressure of Atmospheres.	Temperature.
Cyanogen	3.7	3.7° C.
Sulphurous Acid	3	7.2°
Chlorine	4	15.5°
Ammonia	6.5	10°
Sulphuretted hydrogen	17	10°
Carbonic acid	36	10°
Nitrous oxide	50	7.2°
Hydrochloric acid	50	10°

Many solids when dissolved in liquids absorb heat. Wine is cooled in India by placing the bottles in water containing crystals of nitrate of potash. The "*eau sucrée*" of the Frenchman is cool because the lumps of sugar are changed in form. The "sherry-cobbler" and "mint julep" of the Yankee are several degrees below the freezing point of water, because two solids, ice and sugar, are rapidly dissolved in sherry or other wine. If liquids rapidly assume the gaseous form a great reduction of temperature results. Thin sheets of ice have been made, even in hot climates, by exposing water in shallow pans to a clear sky at night, to secure speedy evaporation of a part of the water.

Dr. Black, of Edinburgh, first clearly enunciated the laws of "latent heat." At the exact point when a solid begins to liqefy by heat, its rise in temperature is arrested until it is all melted. A similar phenomenon occurs when the visible liquid changes to an invisible gas. The heat required for this transformation is vastly greater. Hence the appropriateness of the term "heat of form." When we would reverse these changes, as from the impalpable to the visible liquid, or solid, we must abstract this heat. In 1834 Thillorier solidified large quantities of carbonic gas by rapidly evaporating the liquefied gas. When the snowy-looking solid is mingled with its solvent ether, a most intense cold results as they both assume the gaseous state. By evaporating them in vacuo, Faraday attained the lowest temperature then known.

Many gases cannot be liquefied by simple pressure. At the "*critical point,*" differing with each gas, the expansive power of heat must be abstracted. Intense cold must coöperate with force. By these combined agencies, in 1877, Cailletet, of Paris, announced to the French "Academy of Sciences" that he had liquefied oxygen, also carbon monoxide, by employing a pressure of 300 atmospheres and by the evaporation of liquid sulphurous acid, reducing the temperature to —29 degrees C. On the same day the following telegram from Raoul Pictet, of Geneva, was read before this society: "Oxygène liquéfié aujourd'hui sous 320 atmosphères, et 140° de froid, par acid sulfureux et carbonique accouplés."

In 1878 Pictet liquefied hydrogen gas, employing a pressure of 650 atmospheres (about five tons) per square inch (!) and a temperature of —140 degrees C. The following table presents at a glance these interesting discoveries:

GASES LIQUEFIED.

	Atmos.	Temp. Cent.
Cyanogen	4	+ 15°
Chlorine	8.5	+ 12°
Ammonia	6.25	+ 10°
Nitrous oxide	40	+ 7.2°
Ethylene	46	+ 4°
Carbon dioxide	54	+ 18.3°
Acetylene	86	+ 15°
Nitric oxide	104	— 11°
Marsh gas	108	— 11°
Nitrogen	300	— 13°
Carbon monoxide	300	— 29°
Oxygen	300	— 140°
Hydrogen	650	— 140°

LIQUEFIED GASES BOIL AT

	C.
Carbon dioxide	— 80°
Nitrous oxide	— 90°
Ethylene	— 103°
Nitric oxide	— 153°
Marsh gas	— 161°
Oxygen	— 184°
Air	— 192.2°, mean — 191°
Carbon monoxide	— 193°
Nitrogen	— 198.1°

The lowest temperatures yet attained are here tabulated:

Faraday with solid carbon dioxide and ether in vac. obtained	— 110° C.
Natterer with solid nitrous ox. and carbon disulphide obtained	— 140° C.
Olzewski by evaporation of liquid air obtained	— 210° C.
Olzewski with solid nitrogen in vac. obtained	— 225° C.

Professor Dewar employed liquefied ethylene (olefiant gas) in producing the intense cold necessary to liquefy the air. One thousand pounds sterling was the liberal contribution of the "Goldsmiths' Company" for the expense of the ingenious means for compressing and cooling the gases. Both M. Cailletet and M.

Pictet spent much money, as well as intellectual work in accomplishing their results.

I have frequently been asked: "Of what use are these interesting, laborious and costly experiments?" To the scientist they have demonstrated that solids, liquids and gases differ in form because of differences in "heat of form." They support the nebular hypothesis as to the primitive condition of our universe. They carry him back to an epoch anterior to *visible* nebulæ, when radiant energies such as heat, light and electricity had not announced themselves—when all was "*without form and void; and darkness was on the face of the deep*" (profound). When the gaseous elements commenced their combination these forces resulted. And God said: "Let there be light, and there was light," generously diffused through immensity. By movements excited, the fluids broke into clusters, suns, planets and satellites. Some cooled to liquids, in the course of immeasureable ages, and became encrusted spheres. On one of these life appeared.

By heat we greatly stimulate chemical affinities. At the low temperatures attained by these ingenious experiments, chemical activities are diminished. Oxygen refuses to burn with carbon, phosphorus and potassium. Chlorine will not unite with elements with which, at common temperatures, it combines with great avidity. Electric conductivity, magnetic relations, spectroscopic effects have been successfully studied with these newly-formed liquids. Paalzow, of Berlin, determined the modulus of elasticity of mercury by the use of this metal frozen in the shape of a tuning-fork. At the frigorific laboratory of Pictet, in Berlin, solid chloroform, alcohol and other chemicals are prepared in purer condition than ever before. Thus, a new era in chemical manufacture has been inaugurated.

Many of these liquefied gases are daily employed for *mechanical* purposes. Fifteen years ago the United States Government propelled torpedo boats with liquid carbonic acid. Two companies are now organized in this city for propelling street cars, one of them by the aforesaid liquid, the other by liquefied ammonia.* When we navigate the air, it will be by the aid of this concentrated power.

*Several years before the death of Commodore Vanderbilt the writer was invited to his residence to discuss the employment of liquid ammonia for street cars. The Commodore said; "It makes me sick to see the poor horses dragging a load of from thirty to fifty passengers on a hot day."

The sunken iron-clad, "Grösser Kurfurst," was floated to the surface of the water by attaching to the vessel gas-tight bags and inflating them from receptacles of liquid carbonic acid. Steel rings on Krupp's most formidable cannon have been placed in position by previously cooling, and thus shrinking, the gun with this liquid. The metallic armatures of the colossal microscope now being constructed in Munich for the World's Fair at Chicago are guarded against the heat of the electric light by the escape of a little jet from a cylinder of liquid carbonic acid. Tons of this liquid are made daily in Berlin and other European cities and exported to this country. In New York the American Carbonate Company have produced it on a large scale for many years. Tens of thousands of wrought iron cylinders, with from ten to twenty pounds of the liquid are sold annually in different parts of the world.

For half a century, water has been frozen in caraffes and in plates of ice, by the evaporation of ether; later with liquefied ammonia, sulphurous and carbonic acids ; also by the sudden expansion of compressed air. Artificial ice from distilled water is a commercial product. Ice is even made for skating rinks. All kinds of meat, game, fish and fruit are preserved by similar means, and could be kept for as unlimited a time as the ancient elephants found by the Russian scientist, Pallas, in Siberia, in 1799, which had been frozen in Nature's ice box. The dogs of the Jackoutes partook of the flesh with evident delight. Besides capacious refrigerating rooms, compartments in cars and ships are artificially cooled for the transportation of articles of diet. One large steamer was exclusively arranged as a floating refrigerator for conveying meat from Texas. Liquefied carbonic acid was employed as the cooling agent.

I have found, after several months' experimenting, that the domestic refrigerator could be kept at 40 degrees F. by the evaporation of liquid ammonia at a less cost than by employing ice. A lower temperature than this is undesirable. In hundreds of breweries, ammonia machines are used for cooling purposes in preference to ice, both for economy and cleanliness ; also for forcing beer from cellars and aerating it.

Since witnessing, in 1847, the experiments of Professor Gmelin, in Heidelberg, with liquid carbonic acid, I have enjoyed years of practical experience in liquefying thousands of gallons of this gas and producing bushels of the snowy solid with Thillorier's apparatus. I have shown it to students in colleges, and at public lectures, where not only a hundred pounds of mercury have often been frozen in a few minutes, but also where electrical phenomena were exhibited, caused by the friction during the rapid escape of the liquid and its sudden change of form. Sparks were drawn from an insulated "prime conductor," and the repulsion of similarly electrified light objects were witnessed by an audience filling the Academy of Music.

About thirty years ago the United States Government appointed a commission to examine and report on methods for saving life on shipboard. I repeatedly exhibited to this commission the efficacy of liquid carbonic acid in extinguishing fires, and suggested that wrought-iron cylinders, filled with this liquid, should be placed on the decks of vessels and connected with iron tubes passing by the side of the stanchions into various compartments. Should spontaneous combustion of cotton, jute, coal, etc., occur, the fire would be instantly extinguished by releasing the gas and driving it by its enormous pressure into the hold of the ship. The commission reported unanimously in favor of this method, and advised the passage of a law by the United States Government requiring all our vessels to be provided with such means for extinguishing fires and saving life.

Similar experiments were also shown to a committee appointed by the "New York Board of Marine Underwriters." The committee commended this mode of putting out fires in the highest terms. It is especially applicable in our bonded warehouses which contain merchandise valued at millions of dollars. By the use of carbonic acid gas, forced in large quantities from the liquid in reservoirs, the fire would not only be instantly extinguished, but no injury would occur to the most delicate fabrics of silk, satin or velvet, as if water or steam were employed.

In 1862 I assisted M. Barthelemy Bianchi in exhibiting before the Academy of Sciences, in Paris, the liquefaction of nitrous oxide gas by a novel form of pump. Interesting experiments were shown with both the liquid and solid "laughing gas." Since that time I have annually exhibited it to students and to the public.

For many years I have urged that these liquefied gases should be utilized to temper the heat of summer in our homes and hospitals, our banks and business offices, our sumptuous edifices for pleasure or piety. I have ventured to say: "If they can cool dead hogs in Chicago, why not live 'bulls and bears' in the New York Stock Exchange?" Citizens would be happier, merchants would make more money, and physicians would save more lives with the temperature at 70 degrees Fahr. than at 90 or 100 degrees.

The surgeon produces local anæsthesia by a spray of ether or a jet of cold gas from liquid nitrous oxide. Dr. Colton administered a dose of laughing gas to Dr. Wells, of Hartford, by his request, in 1844, and a tooth was extracted without pain. Now the liquefied gas is sent to all parts of the world for dental purposes. This anæsthetic, which has been inhaled by some patients for over an hour, is esteemed by many eminent surgeons and obstetricians as the safest of all. Fewer fatal results have occurred by its use than from the employment of ether or chloroform. Methyl chloride has been introduced so recently that a comparison cannot be made. The anæsthetics are the greatest blessings chemistry has offered at the shrine of medicine.

Liquefied chlorine and sulphurous acid are sold for bleaching purposes. They are also most efficient disinfectants. In the summer of 1865, I was authorized by Mayor Gunther to disinfect vessels entering New York harbor from certain foreign ports, where cholera existed. During the voyage of one of these steamships, the "Atalanta," sixty passengers had died from this disease. Chlorine was generated in enormous volumes in this ship, and in all the vessels from infected places. No case of this dreaded malady appeared in our city, proving the efficiency of chlorine. In the surgical wards of Bellevue Hospital, the walls of which had become magazines of disease, over two tons of chlorine gas were successfully employed by the writer to destroy the malign agents; following them effectively through plaster and stone walls. It has since then been applied in many hospitals.

Liquid chlorine, or sulphurous acid (the gas produced by burning sulphur) can now be handled in compact form, and liberated in rooms, where typhus, small-pox, scarlet fever, diphtheria, or other fearful maladies have injured or slain their victims. The records in our daily journals, within a few weeks, tell us that the luxurious mansions and hotels of our city can boast of no exemption from contagion.

R. OGDEN DOREMUS.